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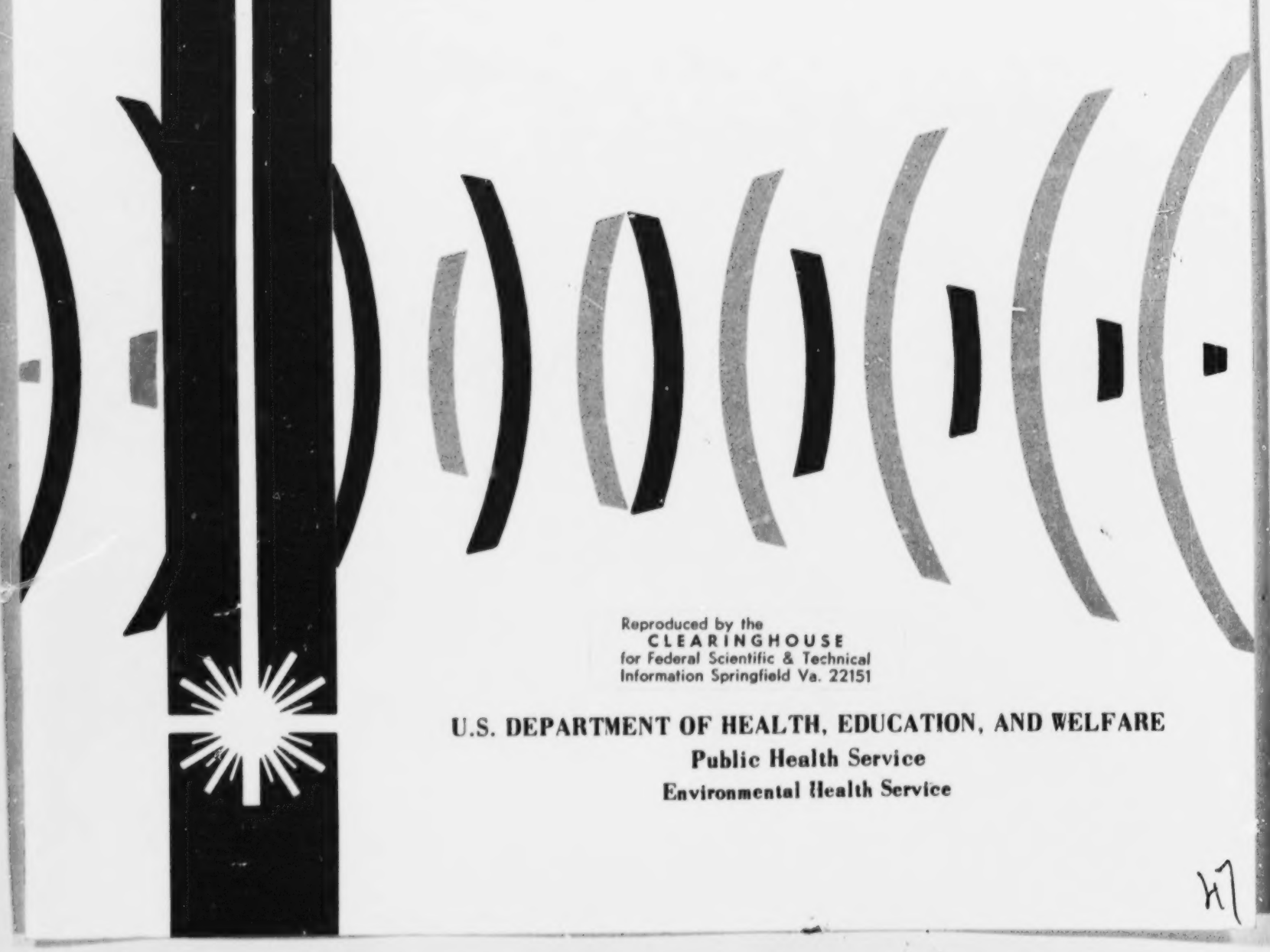
# A STUDY OF HEAD AND NECK EXPOSURES FROM PANORAMIX® ROENTGENOGRAPHY



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BRH/DEP 70-5

# A STUDY OF HEAD AND NECK EXPOSURES FROM PANORAMIX® ROENTGENOGRAPHY

James J. McMahon, D.D.S.

X-ray Exposure Control Laboratory
Division of Electronic Products

March 1970

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
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# FOREWORD

The Bureau of Radiological Health, formerly the National Center for Radiological Health, continues to carry out a national program designed to reduce the exposure of man to hazardous ionizing and nonionizing radiation.

Within the Bureau, the Division of Electronic Products (1) develops and administers performance standards for radiation emissions from electronic products, (2) studies and evaluates emissions of and conditions of exposure to electronic product radiation and intense magnetic fields, (3) conducts or supports research, training, development, and inspections to control and minimize such hazards, and (4) tests and evaluates the effectiveness of procedures and techniques for minimizing such exposures.

The Bureau publishes its findings in Radiological Health Data and Reports (a monthly publication), the Environmental Health Series, Public Health Service numbered reports, appropriate scientific journals, and Division technical reports.

The technical reports of the Division of Electronic Products (DEP) allow comprehensive and rapid publishing of the results of intramural and contractor projects. The reports are distributed to State and local radiological health program personnel, Bureau technical staff, Bureau advisory committee members, university radiation safety officers, libraries and information services, industry, hospitals, laboratories, schools, the press, and other interested individuals. These reports are also included in the collections of the Library of Congress and the Clearinghouse for Federal Scientific and Technical Information.

I encourage the readers of these reports to inform the Bureau of any omissions or errors. Your additional comments or requests for further information are also solicited.

John C. Villforth
Director
Bureau of Radiological Health

# PREFACE

This publication describes an in vivo/in vitro radiographic investigation, involving a technique of examination based upon a unique design of equipment. A physical evaluation of the x-ray machine itself was concurrently accomplished, as described in a separate Division of Electronic Products publication.

The National Council on Radiation Protection and Measurements has recommended guidelines in its official publications which govern certain aspects of usage of dental and medical diagnostic x-ray machines. However, care must be exercised in the interpretation and enforcement of some of these recommendations to avoid stifling innovations and progress in the design of new equipment or techniques which contribute to the advancement of diagnostic radiology. For this reason, the Westinghouse Panoramix® intracavitary diagnostic x-ray machine was investigated as described herein.

The objectives of these scientific investigations were to examine critically the contribution of such a device to the healing professions, whether it would meet accepted standards and if the use of x rays in this manner would be judicious and effective.

Robert L. Elder, Sc.D.
Acting Director
Division of Electronic Products

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# A STUDY OF HEAD AND NECK EXPOSURES FROM PANORAMIX® ROENTGENOGRAPHY

## 1. INTRODUCTION

This study is part of a series of investigations being conducted to determine body exposures from ionizing radiation during oral roentgenographic examinations. The information obtained will assist the Bureau of Radiological Health in formulating guidelines and recommendations of diagnostic techniques, intended to minimize radiation exposure to dental patients.

The National Committee (now Council) on Radiation Protection and Measurements (NCRP), in NBS Handbook No. 76 (1) has recommended that a target-to-skin distance, or source-skin-distance (SSD), of not less than four inches be used for dental radiographic units operating below 50 kV, and of not less than seven inches for units operating above 50 kV.

NCRP Report No. 33 (2) says that an SSD less than 12 inches shall not be used in medical radiography.

The International Commission on Radiological Protection, in their ICRP Publication No. 3 (3), states that contact radiography is dangerous and should be avoided whenever possible.

With the advent of intracavitary medical/dental x-ray machines, i.e. the Panoramix(R) and the Status-X[1] which were designed to operate during body contact, a conflict has arisen as a result of a set of recommendations which did not foresee, nor intentionally prohibit, this unique design.

If these recommendations are enacted as law as in many states, literal interpretation of the foregoing requirements and a rigid enforcement would nullify the intended advantage of these devices for diagnostic examinations.

---

[1]Trademark, Siemens Aktiengesellshaft, Medical Division, Erlangen, Germany

Several investigations of Panoramix radiography have been published within this decade, none of which were cause for alarm in themselves. Nevertheless, some concern regarding its safety has been raised for the lack of any comprehensive dosimetric evidence. A notable example of this attitude and its effect is the prohibition of sales of such equipment in the State of Illinois. Or the inevitable question: "How high a dose does the tongue get?", frequently is heard from concerned health authorities.

The primary objective of this investigation was to obtain accurate data concerning exposures to critical organs and tissues of interest of the head and neck, when using the Panoramix x-ray machine for oral diagnostic roentgenographic procedures. Knowledge of exposures to tissues expected from using this unique intraoral x-ray source to obtain an extraoral panograph was needed by public health authorities and clinicians, to better appreciate the usefulness and limitations of this device.

A logical sequence requires a decision which either further validates the current recommendations or regulations as they exist to date or a suggestion for an appropriate amendment.

## 2. EQUIPMENT

### 2.1 X-ray Unit

The Westinghouse Panoramix x-ray machine has been fully described by Woodcock and Properzio (4), and is only briefly described here.

This type of unit as shown in figures 1, 2, and 3 was designed to provide an x-ray source of such size and shape as to permit radiography of structures from within body cavities or openings. Such orifices can be either natural or surgically created. Also, body protuberances, such as the joints, or smaller bones, e.g. zygomatic arch of the face, etc., may be more readily radiographed with this type of equipment, since proper positioning to obtain the desired view with conventional x-ray units may be more difficult (5,6,7).

A filtration sleeve of 2-mm Al was provided as an accessory which slips over the aluminum tube covering. A ring near the distal end of the filter cylinder marks the plane of the focal spot, 11/32 inch from the end of the tube cover. An accessory collimating shield, which slips over the tube cover is also provided, but the shield and the filtration sleeve cannot be used together (fig. 3).

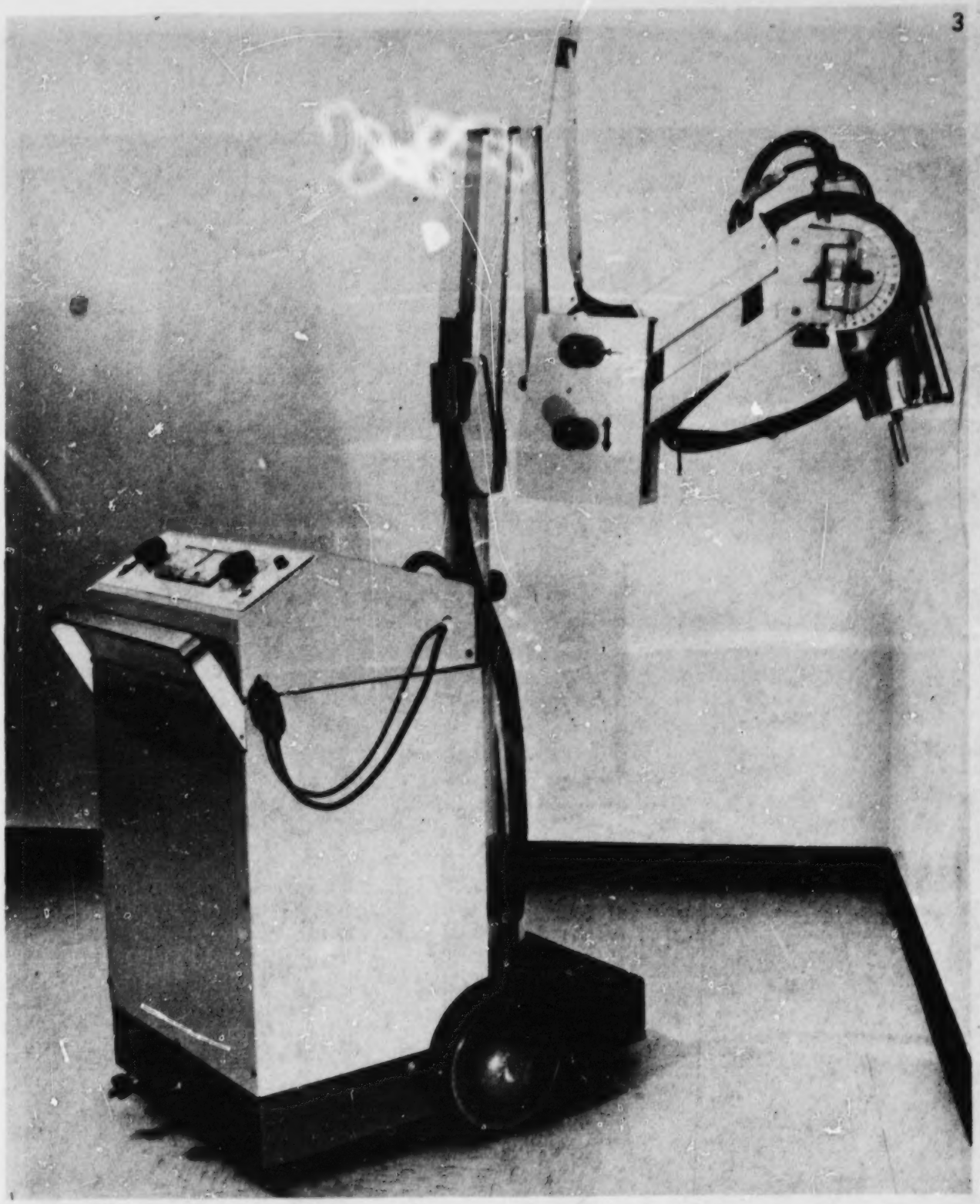

Figure 1. The Panoramix, Westinghouse model MO-200

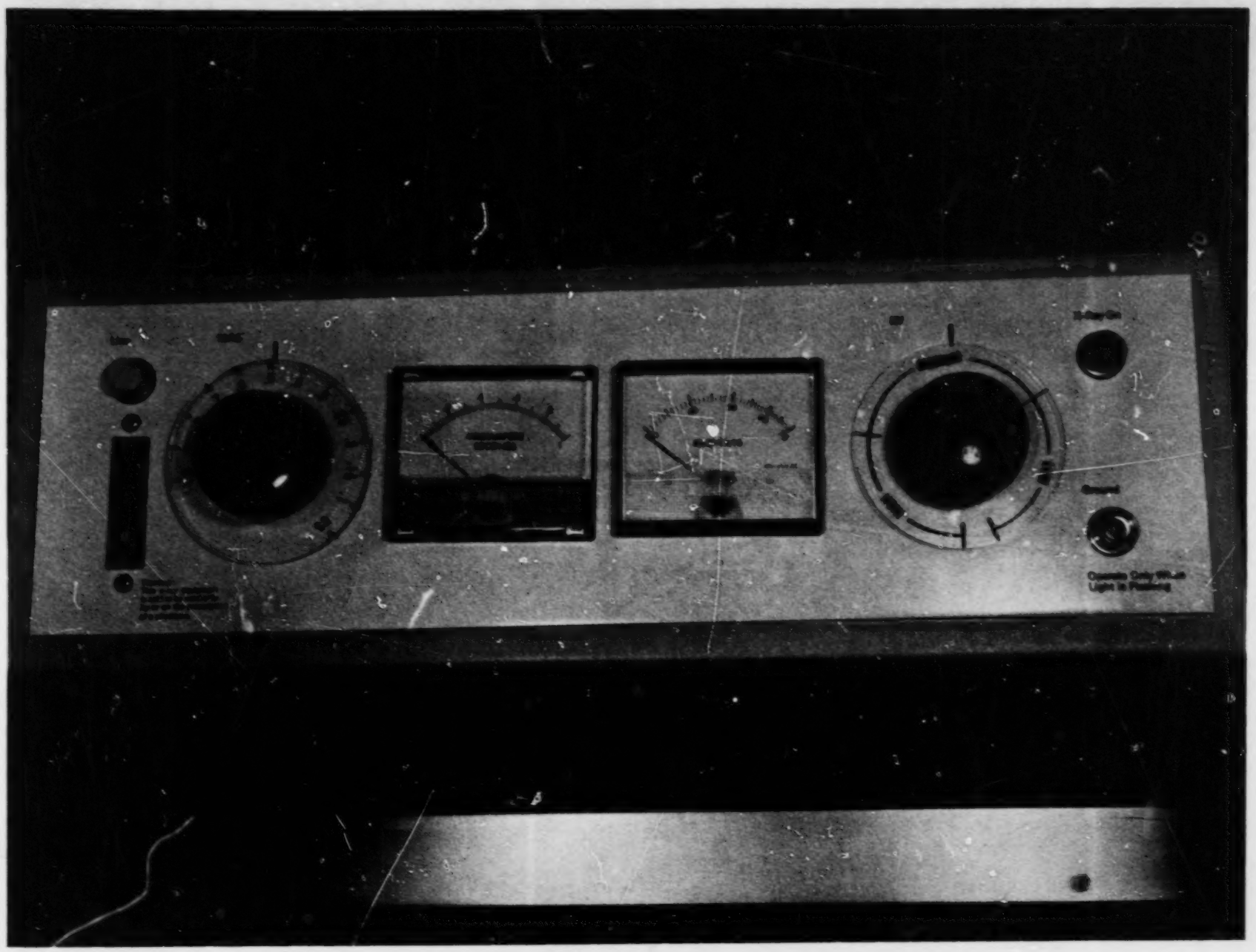

Figure 2. Panoramix control panel

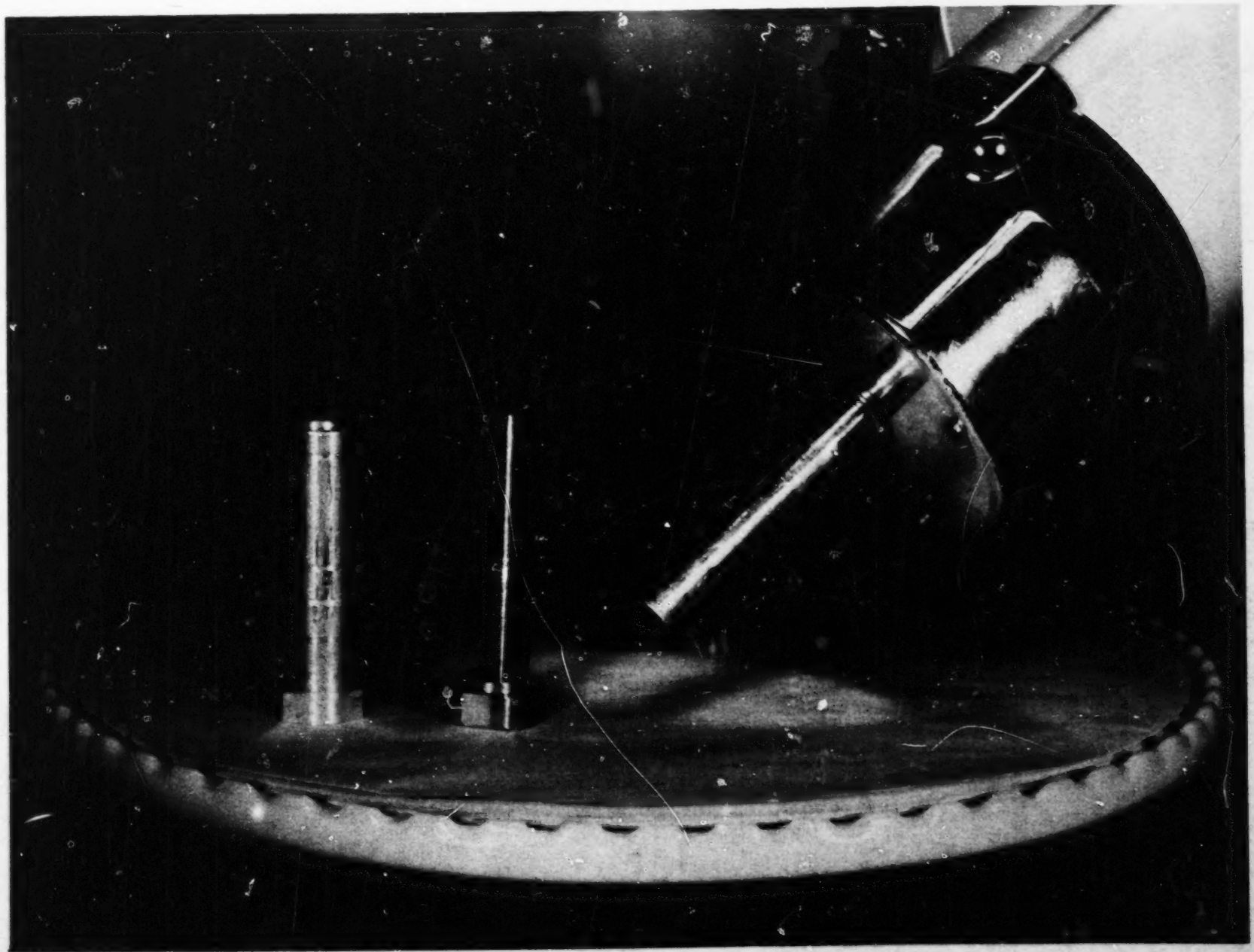

Figure 3. Panoramix. Tube filtration cylinder (left), beam limiting shield (center)

The line voltage used with this machine throughout this experiment was set and maintained at 115 V with an automatic line voltage regulator[1].

## 2.2 Phantom

A commercial phantom[2] was used for the laboratory investigation. It consisted of an intact human skeleton, properly positioned within an average man-sized torso and composed of a compound of tissue equivalent, thermoplastic, isocyanate rubber to simulate soft tissue in radiodiagnostic and therapy energy ranges. The phantom contained the oro-nasal airways, the oral cavity, sinus air spaces, trachea, stem bronchi, and foam plastic lungs. The phantom body had no extremities, (fig. 4).

For dosimetry purposes, the phantom was sliced transversely into sections 2.5 cm thick and numbered 0-35. Holes 5 mm in diameter were drilled vertically throughout on a 3-cm grid array. The holes were marked, but not drilled if more than half the material to be removed was dense bone. The drilled holes were all provided with tissue equivalent plugs of Mix "D".

## 2.3 Detectors

The dosimeters used in this study were extruded rods[3] of TLD-100 lithium fluoride, weighing approximately 27 mg each and measuring 1 mm x 6 mm. The standard error of an integrated light output reading for these rods was 10 percent at 10 mR and 3 percent at 1 R. Lithium fluoride thermoluminescent dosimeters were selected as detectors because of their near tissue equivalence, minimal energy dependence, wide useable dosage range, negligible fading of the latent dose-proportional stored energy, high precision for routine use, and small convenient size (8).

The TLD reader[4] featured a digital output and automatic post irradiation annealing prior to readout to remove low temperature glow peaks which reduce precision of measurement.

---

[1]General Radio, Type 1570-A, West Concord, Massachusetts
[2]Alderson-Machlett Tando Phantom of Alderson Research Laboratories, Inc. Long Island City, New York
[3]Type TL-024, Edgerton, Germeshausen and Grier, Inc., Goleta, California
[4]Model TLR-5, Eberline Instrument Corp., Santa Fe, New Mexico

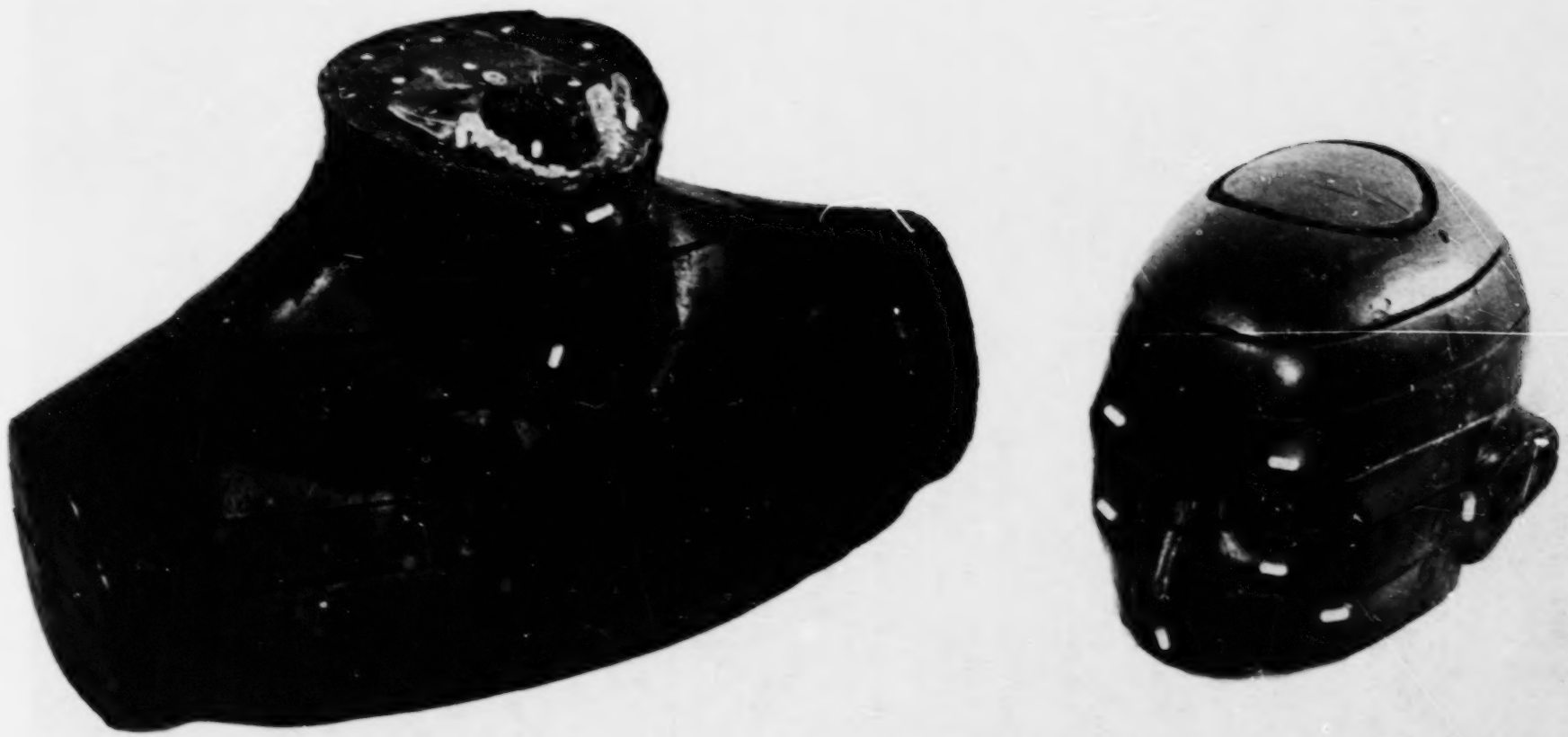

Figure 4. The Alderson-Machlett Rando Phantom. Bust section of the partial body, sectioned model. Capsules positioned in/on pre-selected, dosimeter sites.

# 3. PROCEDURES

## 3.1 Dosimetry

Because it was impractical to obtain accurate measurements of minute exposures of X-radiation at remote areas of the body, the study was confined to the exposures to the head and neck area from oro-facial radiographic procedures.

Dosimeters were placed in the grid array throughout the phantom, sections 0-10 (fig. 4). Various structures of interest were considered in selecting placements within the grid as shown on page 17. External locations coincided with similar preselected dosimeter sites on clinical patients in a parallel study as described in part 3.6 and listed on page 19. Thus, the equivalence of the Rando phantom in comparison with people could be established from assessments obtained between corresponding locations on either type of subject.

For each laboratory and clinical study, the dosimeters were prepared by annealing in a brass plate for 1 hour at 400°C, and allowed to cool to room temperature. Control dosimeters were then calibrated with a medical x-ray unit[1] at each operating kilovoltage and filtration used on the Panoramix. (Consideration was given to different voltage waveforms of the Panoramix and the calibration x-ray units). The unexposed dosimeters were retained as background controls. All the dosimeters were calibrated in milliroentgens (mR), a unit of exposure. All experimental measurements have been recorded in mR, in the sense of being an "mR equivalent dose", rather than millirads (mRAD), a unit of absorbed dose. This was done not only for experimental convenience in presenting the data, but also to more readily relate to almost all previous investigations as contained in the scientific dental literature to date.

The dosimeters were enclosed in #5 gelatin capsules. They fitted easily into the phantom drilled holes, and readily attached onto the surfaces of the phantom and human subjects. After each test run was made at a specific combination of operating parameters, the TLD capsules were removed and the dosimeters read.

---

[1] G.E. Maximar-100® General Electric Corporation, X-ray Division Milwaukee, Wisconsin

## 3.2 Parameters

The x-ray exposure parameters used for the study were potentials of 50 and 65 kVcp and total filtration of 1.8 and 3.8 millimeters of aluminum for each operating potential kV. These respective filtrations had occurred when either the collimating shield or the aluminum filter sleeve was utilized. At no time could the shield and filter be employed simultaneously.

Although the operator's technique manual described procedures using only 50 kVcp, a higher kilovoltage technique was included in this study for several reasons. The kV range of the Panoramix is 30-70; the diagnostic range used in dentistry is 50-100 kV. Therefore, data would be needed at the upper limit of the machine potential. Also, because the scientific literature contains more references regarding radiation exposure measurements from 65-kV techniques than any other, there would be a larger body of available information for comparison.

The aluminum filtration cylinder was utilized to vary the beam quality and thus vary the image quality of the radiographs. It also assisted in tube positioning by permitting the operator to gauge the depth of insertion of the anode into the oral cavity from the marking rings on the cylinder. Consideration was also given to its dose reduction potential

## 3.3 Examinations

On each of the maxillary and mandibular projections, and the single multipurpose projection, the tube anode was inserted about 4 to 6 cm into the oral cavity (fig. 5). It was angulated 20° upward for the maxillary, 0° for the combination, and 20° downward for the mandibular films, from a plane parallel to the Frankfort plane (ala-tragus line).

Under darkroom conditions, an 8-inch x 10-inch fast nonscreen medical x-ray film in a light-tight packet[1] was cut into two 4-inch x 10-inch halves and resealed light tight. Each one was wrapped about the face for the appropriate maxillary or mandibular projection. Each film was held in place by the film holder which was attached to the tube-head housing for this purpose (figs. 6,7).

---

[1]Kodak No-Screen Ready Pack Code NS-2T, Eastman Kodak Co., Rochester, New York

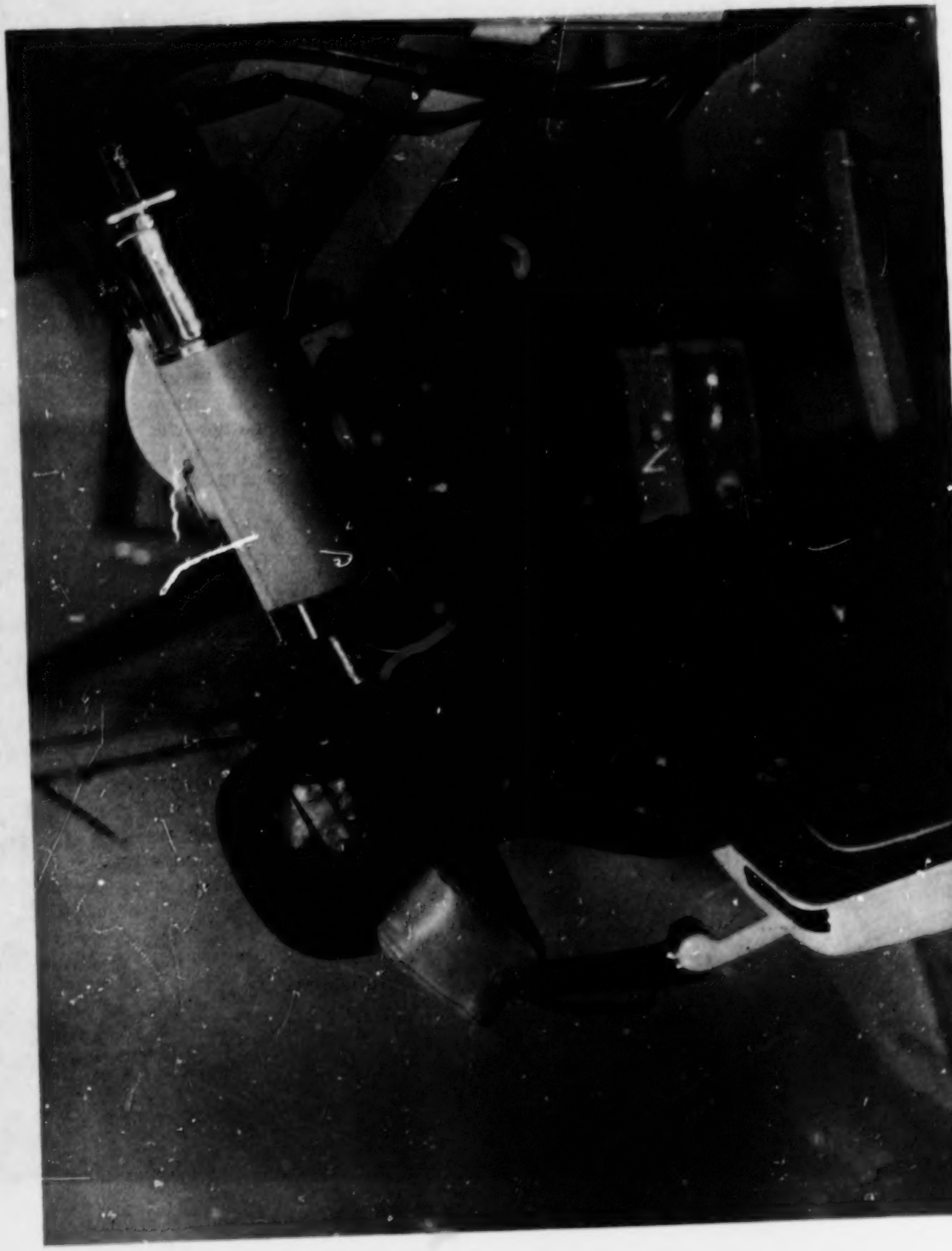

Figure 5. The phantom and the Panoramix

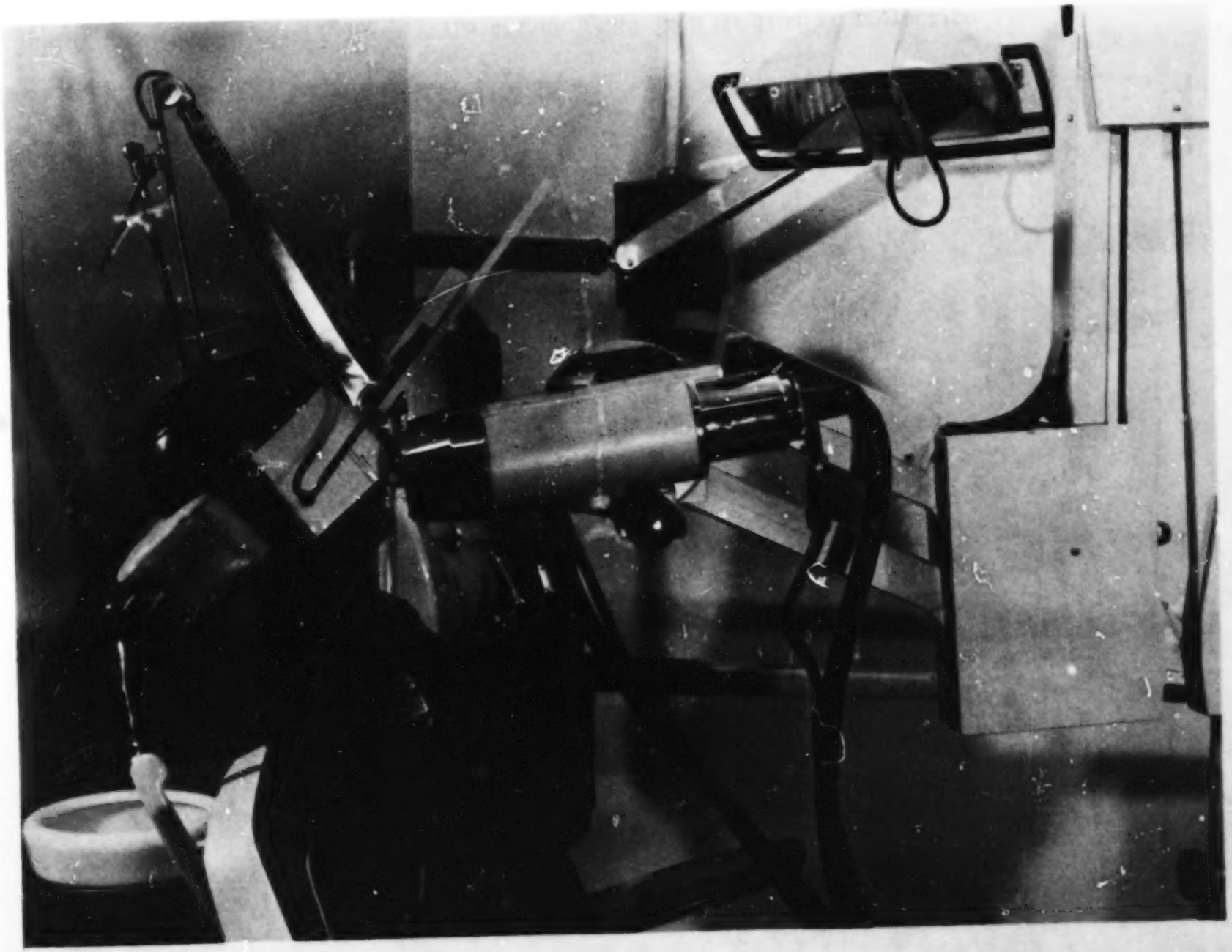

Figure 6. The 4-inch by 10-inch maxillary projection

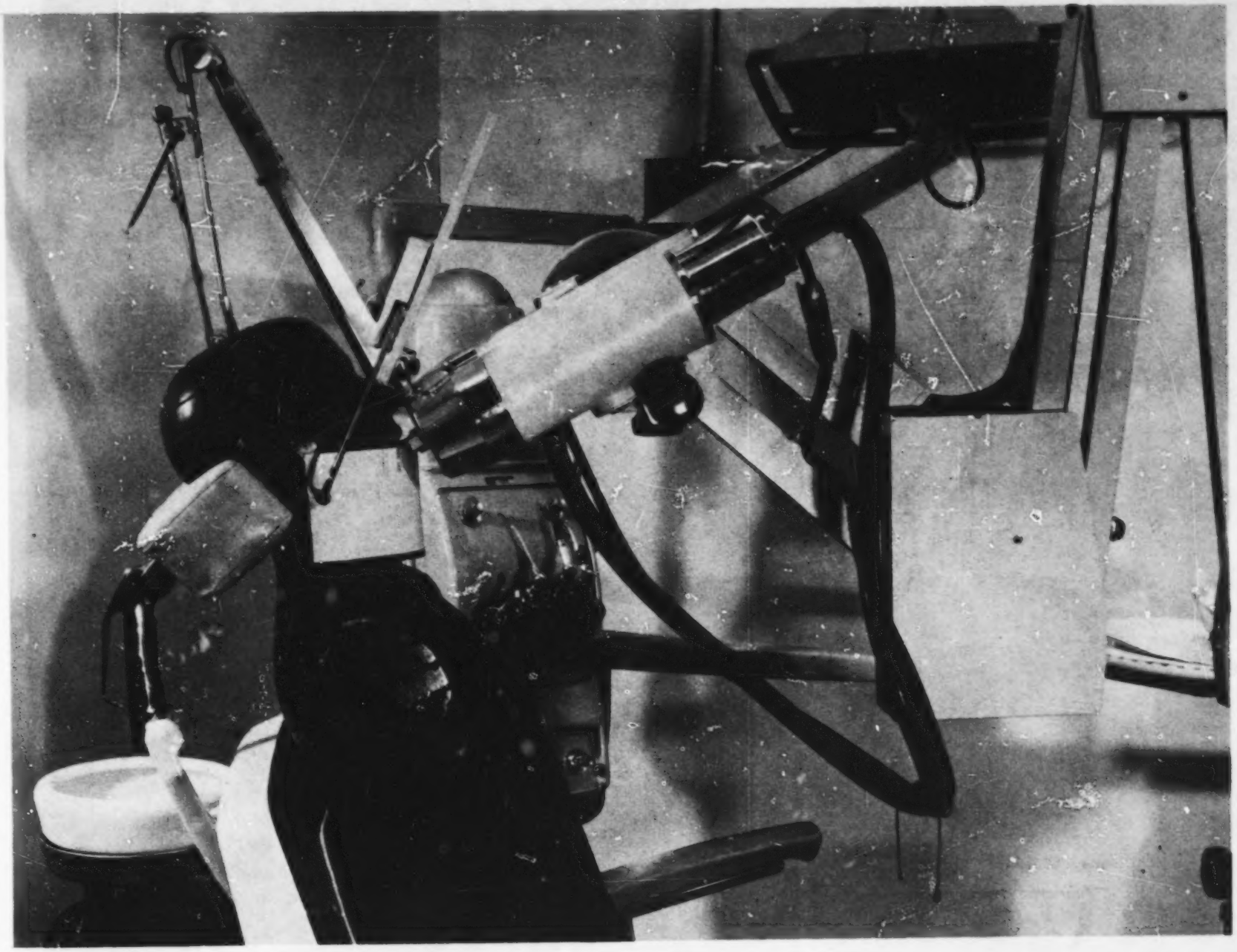

Figure 7. The 4-inch by 10-inch mandibular projection

The 8-inch x 10-inch multipurpose film technique required that a center hole be punched through the film packet and resealed light tight, in order to permit the anode to pass through the film, and into the mouth of the subject (fig. 8).

The phantom was reassembled exactly for each test series. The machine and films were repositioned for each projection as needed.

Each beam quality and projection aforementioned was tested separately. In order to obtain measurable quantities of ionizing radiation to the remote sites for greater accuracy in the phantom dosimetry, all exposures were intentionally increased by a constant factor. After the data were collected, appropriate reduction factors were applied to calculate the exposures corresponding to a properly exposed film, as defined in the film study, part 3.5. Care was exercised to remain within the duty cycle of the x-ray generator, and to obtain high enough intensities and integrated doses to insure dosimeter accuracy.

## 3.4 Scatter Study

Concurrently with the phantom assessments, measurements of scattered radiation were taken at 60-degree intervals around the phantom at a height of 0.75 meters from the floor and one meter from the anode, which was positioned within the oral cavity of the Rando phantom.

An ionization chamber[1] instrument integrated the exposures accumulated at the specified points on the circle. Relative to the Phantom-Panoramix axis, zero degrees was in back of the "patient" in the chair.

## 3.5 Diagnostic Film Study

In order that dosimetry should be directly related to diagnostic radiographic quality, radiographs of the phantom duplicating clinical nonscreen conditions were produced. To determine appropriate film densities, the exposure quantities (mAs) for each of four x-ray beam qualities during three projections were derived from a method suggested by Wuehrman (9).

---

[1]Model 666, Victoreen Instrument Corp., Cleveland, Ohio

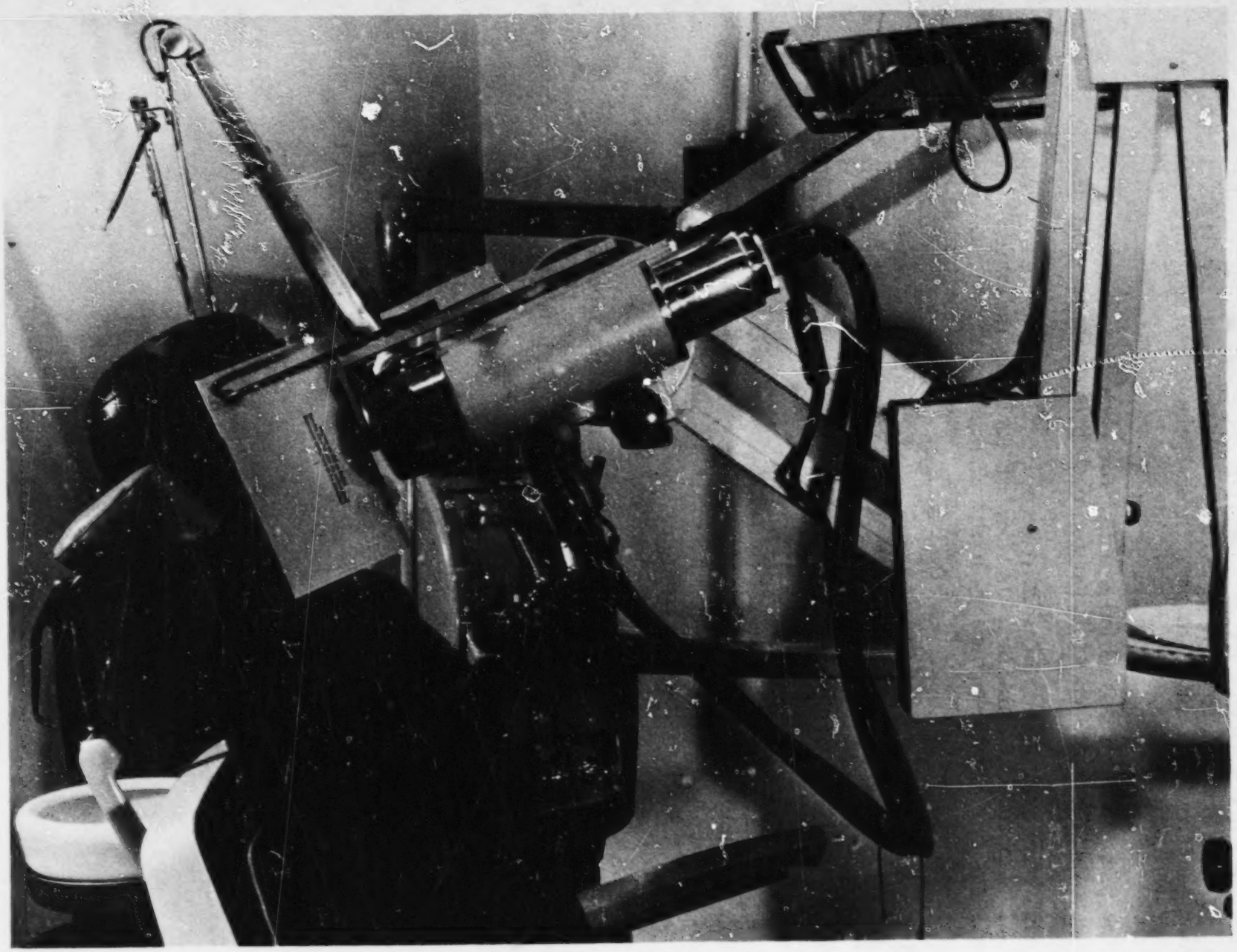

Figure 8. The 8-inch by 10-inch projection

From a series of increasingly dense radiographs taken on the phantom, each of a panel of clinicians consisting of eight dentists and three radiologists indicated his preference regarding a properly exposed film (table 1).

The mAs dial settings nearest to the average of the selections expressed by the panelists were used as the correct exposures for the clinical radiographs described below.

All the films were processed under identical conditions, in accordance with the film manufacturer's recommendations.

Table 1. Diagnostically acceptable radiographs, percentage of clinicians who preferred the radiographs produced with the indicated parameters

| Potential kVcp | | 50 | | 65 | |
|---|---|---|---|---|---|
| Total Filtration mm Al | | 1.8 | 3.8 | 1.8 | 3.8 |
| mAs | 0.05 | - | - | 73% | 5% |
| | 0.10 | 59% | - | 27% | 77% |
| | 0.20 | 41% | 68% | - | 18% |
| | 0.40 | - | 32% | - | - |
| | 0.80 | - | - | - | - |

3.6 Patient Study

A parallel clinical study, necessarily limited to ten patients, was then conducted in accordance with current recommended practices, observing proper radiation protection measures; i.e., fact-speed film, full development, tube collimating shield or filter sleeve, barriers, etc. TLD were placed on the patients at sites common to those used on the phantom, for each duplicate diagnostic procedure. The clinical radiographs were made from the same type nonscreen medical x-ray film in light-tight packs as described in part 3.3.

### 3.7 Screen Film Study

Attempts were also made to produce radiographs of a phantom using a screen-film technique. The 5 inch x 10 inch accessory, flexible, intensifying screen cassette, employing a slow-speed screen, was loaded with a screen-type medical x-ray film[1]. The lowest diagnostically acceptable potential (50) kV and filtration (1.8 mm Al) and lowest exposure setting possible with the controls (0.05) mAs were selected to produce x-ray films of the phantom.

## 4. RESULTS

### 4.1 Phantom

Table 2 lists the exposures measured at 47 sites during four different radiographic examinations. An examination consisted of either a combination of two 4-inch x 10-inch films, one of the maxilla and one of the mandible, or a single 8-inch x 10-inch film of both jaws. Each exposure at 50 kVcp required 0.25 mAs with the filter, and 0.15 mAs without. For 65 kVcp, 0.05 mAs was necessary without filter, whereas 0.01 mAs was needed with filter. These mAs quantities produced the best radiographs as determined by the panel of clinicians.

The exposure levels for the ventral tongue and palatal surface dosimeters showed a range of 200-3000 mR. Corresponding internal sites revealed a 100-750-mR span. The buccal or cheek dosimeters averaged about 100 mR. All these, however, were considerably influenced by tube proximity, TLD geometry, and tissue depth.

The radiation measurements near the tube showed that the use of lower kilovoltages and less filtration resulted in the higher exposure values. Increased distance tended to equalize radiation levels, irrespective of original beam quality, as discussed later in 5.3.

### 4.2 Screen Films

The attempts to simulate phantom radiographs, using screen-type film in the flexible, intensifying screen cassette were unsatisfactory. The resultant films were all overexposed and not acceptable. Therefore, no dosimetry for this technique was possible in this investigation.

---

[1]Kodak Blue Brand, Code BB-54, Eastman Kodak Co., Rochester, N.Y.

Table 2. Dosimeter sites in rando phantom

Exposures in Milliroentgens Per Complete Mouth Examination

| Section | Dosimeter location | Films/exam | Two 4 by 10-inch | | One 8 by 10-inch | |
|---|---|---|---|---|---|---|
| | | Total filtration (mm Al) | 1.8 | | 3.8 | |
| | | kVcp-mAs/film | 50-0.15 | 65-0.05 | 50-0.25 | 65-0.10 |
| I | Gyrus, anterior central | | 1.9 | 1.2 | 2.3 | 2.5 |
| | Gyrus, posterior central LR avg.[a] | | 0.4 | 0.4 | 0.9 | 1.0 |
| | Falx cerebri | | 0.2 | 0.2 | 0.4 | 0.8 |
| II | SUPRAORBITAL RIDGE[b] LR avg. | | 2.5 | 1.1 | 2.7 | 2.5 |
| | Frontal bone LR avg. | | 2.1 | 2.0 | 2.9 | 2.5 |
| | Parietal bone LR avg. | | 0.1 | 1.0 | 0.3 | 0.4 |
| III | Lens of eye | | 21.1 | 12 | 19 | 12 |
| IV | INFRAORBITAL RIDGE LR avg. | | 20.5 | 16 | 21 | 13 |
| | TEMPEROMANDIBULAR JOINT LR avg. | | 2.5 | 1.6 | 2.9 | 8 |
| | Sella turcica | | 7 | 4 | 15 | 15 |
| | Cerebellum LR avg. | | 0.6 | 0.5 | 0.8 | 1.2 |
| V | PHILTRUM | | 55 | 29 | 30 | 20 |
| | MALAR EMINENCE LR avg. | | 21 | 14 | 23 | 15 |
| | Palate (internal) | | 490 | 60 | 250 | 180 |
| | PALATE (surface) | | 3200 | 460 | 980 | 600 |
| | Medulla oblongata | | 0.8 | 0.8 | 1.2 | 1.7 |
| | OCCIPITAL, SKIN | | 0.2 | 0.2 | 0.2 | 0.3 |
| VI | MAXILLARY MOLAR LR avg. | | 210 | 80 | 220 | 100 |
| | Uvula | | 37 | 20 | 46 | 42 |
| | MANDIBULAR MOLAR LR avg. | | 64 | 50 | 51 | 63 |
| VII | LABIO-MENTAL SULCUS | | 43 | 34 | 83 | 60 |
| | Body of mandible LR avg. | | 100 | 66 | 68 | 65 |
| | Tongue (internal) | | 390 | 240 | 220 | 140 |
| | TONGUE (under) | | 800 | 200 | 280 | 210 |
| | Parotid gland | | 31 | 26 | 23 | 15 |
| VIII | Submaxillary gland LR avg. | | 78 | 50 | 50 | 40 |
| IX | Thyroid (internal) LR avg. | | 15 | 12 | 12 | 11 |
| X | THYROID, SKIN | | 5.8 | 4.9 | 7.6 | 5.8 |
| | Thyroid (internal) LR avg. | | 4 | 3 | 3 | 3 |
| | Body C7 | | 0.5 | 0.7 | 0.8 | 0.7 |

[a]LR avg. is the average of left and right dosimeter sites.

[b]Capitalized anatomical designations are sites common to both the phantom and clinical patients.

## 4.3 Patients

Table 3 lists the average exposures per examination measured in clinical subjects. The examination parameters were identical to those used with the phantom. The dosimeters were situated as closely as possible to the same anatomical sites as on the phantom and were attached to the skin and mucosa. Sealed tygon tubes, in lieu of gelatin capsules, were used intraorally, since gelatin is soluble in saliva.

Again, as in the phantom, in regions of close proximity to the tube, there is considerable latitude in the palatal-lingual exposure measurements of 200 mR-1900 mR. Radiation levels in the buccal vestibule were 47 mR to 220 mR.

Facial levels were measured at 6 mR to 46 mR. The maximum and minimum levels for the occiput were 1 mR and 0.3 mR respectively.

The skin dosimeters at the infraorbital and thyroid sites indicated 10-35 mR and 3-7 mR, respectively.

## 4.4 Correlation Between in Vitro/Vivo Subjects

The dosimeter site nearest to the tube, the midsurface of the palate, received average exposures per examination of 0.3-1.9 R for the four techniques listed in table 1 within the group of patients. The corresponding exposures in the phantom were 0.5-3.2 R.

Exposure values obtained close to the anode are not in complete agreement, because the exposure rates decrease very rapidly with increasing distance, making numerically reproducible measurements virtually impossible. This is most evident in the immediate vicinity of the tube.

Figure 9 represents a composite of the data derived from two common sets of dosimeter placements (palate-tongue) nearest the anode, under similar conditions. The behavior pattern of exposure values is analogous, in corresponding groups. The exposure levels have a wide latitude, but good agreement exists. It is evident that the lowest exposures occur with the greater filtration-higher kV; the highest with the low kV-low filtration techniques.

Figure 10 gives evidence, in the phantom, of a close relationship of the infraorbital exposures to those of the lens. Similarly, the external and internal thyroid exposures are closely related. In the orbital regions, the phantom exposure values are half the amounts received by the humans. The respective "skin" thyroid exposures between subjects however, are almost the same.

Table 3. Dosimeter sites on clinical patients

Average Exposures in Milliroentgens Per Complete Mouth Examination

| Dosimeter Location[a] | Films/exam | Two 4 by 10-inch | | One 8 by 10-inch | |
|---|---|---|---|---|---|
| | Total Filtration (mmAl) | 1.8 | | 3.8 | |
| | kVcp-mAs/film | 50-0.15 | 65-0.05 | 50-0.25 | 65-0.10 |
| Supraorbital ridge LR Av. | | 8 | 8 | 8 | 5 |
| Nasion | | 11 | 9 | 6 | 12 |
| Infraorbital ridge LR Av. | | 35 | 35 | 19 | 10 |
| Temperomandibular joint LR Av. | | 5 | 5 | 4 | 14 |
| Philtrum | | 35 | 27 | 20 | 18 |
| Malar eminence LR Av. | | 20 | 18 | 15 | 13 |
| Palate, mid (surface) | | 1900 | 1200 | 330 | 430 |
| Occipital, skin | | 1.3 | 1.0 | 0.3 | 0:4 |
| Maxillary Molar, (side) LR Av. | | 73 | 82 | 220 | 120 |
| Mandibular molar, (side) LR Av. | | 190 | 50 | 51 | 47 |
| Labio-mental sulcus | | 46 | 40 | 19 | 26 |
| Tongue (under) | | 880 | 490 | 230 | 200 |
| Thyroid, skin | | 6 | 6 | 3 | 6 |

[a]Selected sites common to the phantom and to clinical patients

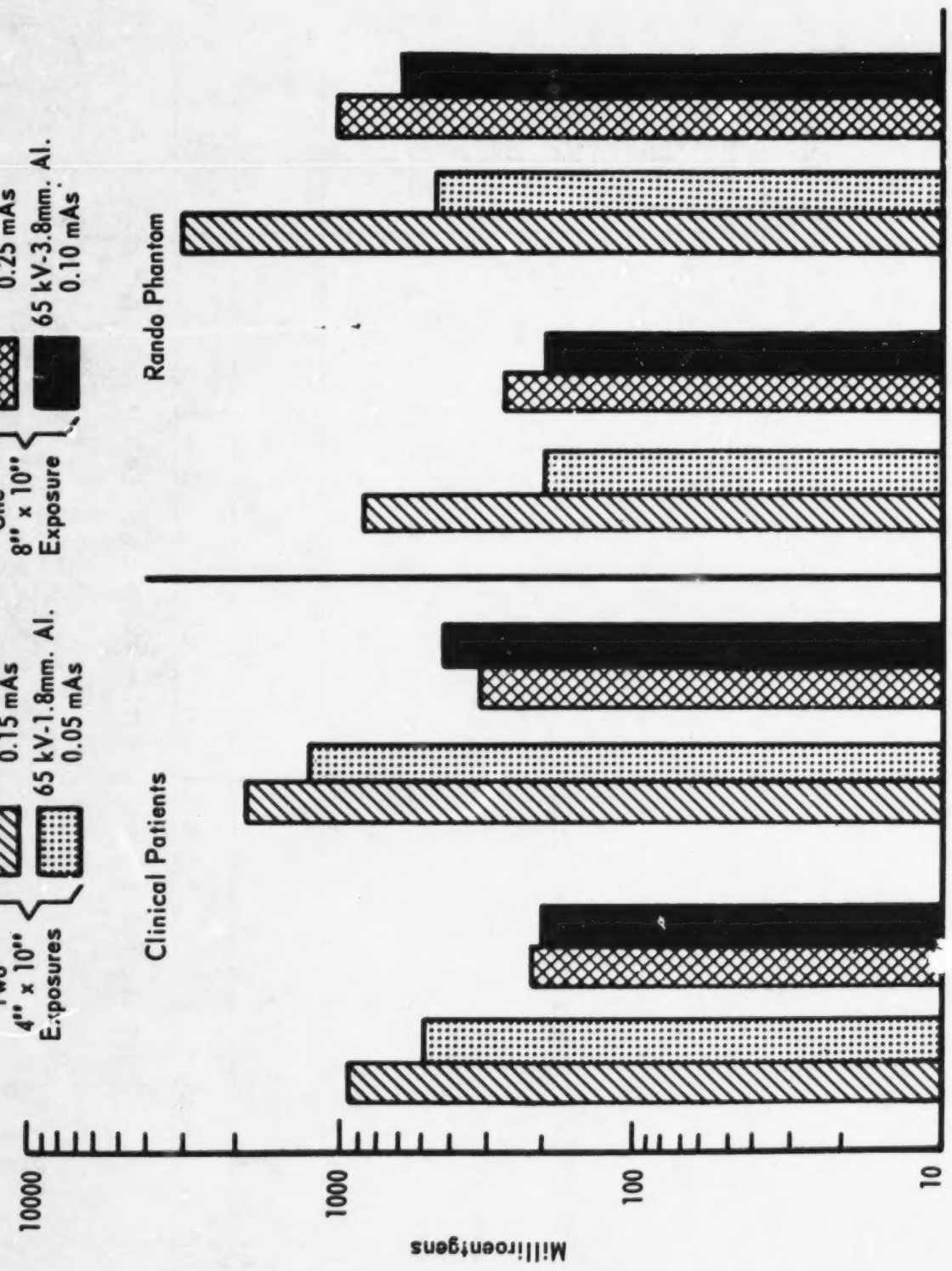


Figure 9. Average exposures in milliroentgens per examination, intra-oral sites

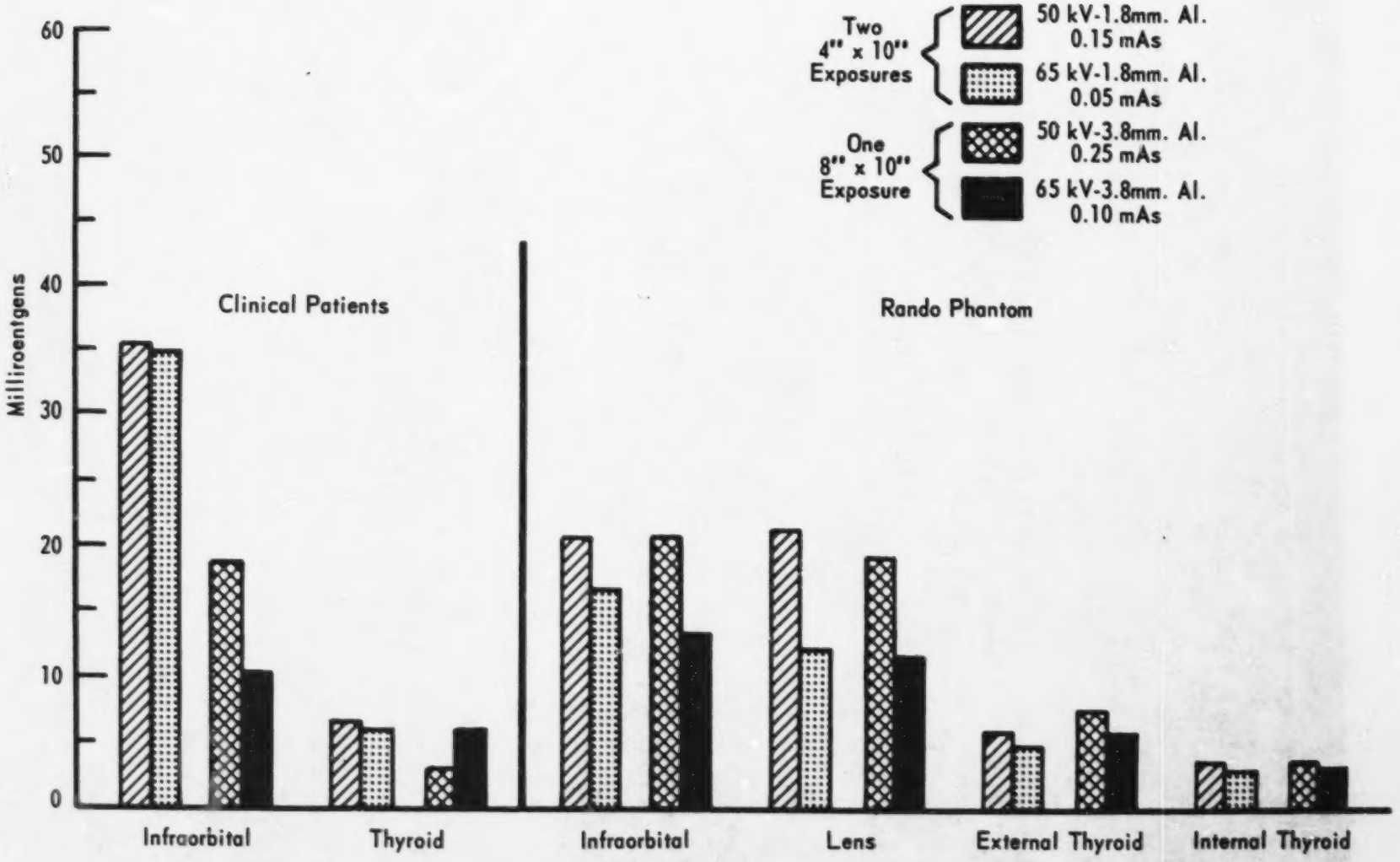


Figure 10. Average exposures in milliroentgens per examination, extra-oral sites

### 4.5 Shielding

The material and design of the tube shield were quite effective in attenuating radiation. At 50 kV the transmission factor is approximately 0.0006 relative to the unshielded tube and the factor increases slightly further from the source (4). Figure 11 is an 8-inch x 10-inch film taken of the phantom at 50 kV with the shield in position on the tube, documenting its directional shielding properties.

### 4.6 Scatter

Figure 12 illustrates the scatter pattern of ionizing radiation, occurring during an examination test run. Two exposures of 4-inch x 10-inch film were made, one each of the maxillary and mandibular projections, using 65-kV and 1.8-mm Al equivalent filtration, and 0.05 mAs per film. The maximum exposure recording (for the total examination) was 0.26 mR, at sitting stool height one meter from the "patient".

## 5. DISCUSSION

### 5.1 Literature Review

Table 4 was compiled as a summary of those references which contained information on "doses" to patients during oral radiography, using the Panoramix. In some instances, comparisons were available from conventional complete mouth techniques.

A difficulty is encountered in attempting to correlate our findings with those of other authors, due to some unknown parameters used in their works. The common denominator, however, is the "diagnostically acceptable radiograph". Other technique factors may then be further adjusted to equitable levels in individual instances to observe the actual similarities reported by different investigators.

### 5.2 Behavior Intraorally

Tube positioning in the mouth, relative to the three projections which were investigated, required the anode placement to vary 2 to 3 cm from the vault of the palate to the depressed tongue surface. This distance results in a reduction factor of about 9 in air, due to inverse square law considerations. In part, therefore, this explains why output information at the tube surface cannot be used directly to determine tissue exposures. Should a proximate surface dosimeter be embedded immediately subsurface, tissue attenuation will cause a further reduction factor of roughly 7, as seen in the internal and external palatal sites in table 2.

Figure 11. Photo of 8-inch by 10-inch radiograph with tube collimator shield

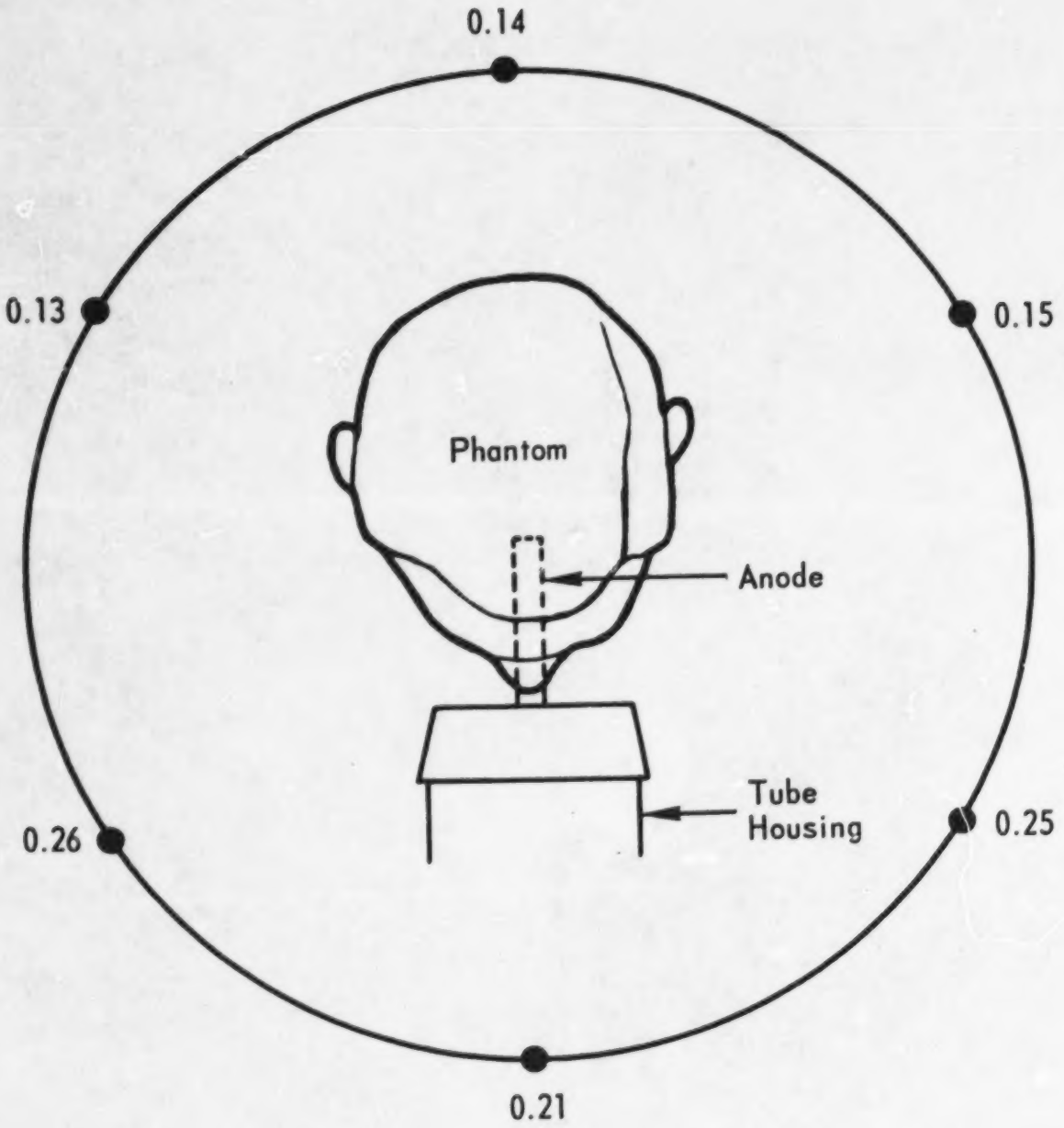


Figure 12. Average exposures in milliroentgens from scattered radiation, from two 4-inch by 10-inch exposures, at 65 kV; 1.8 mm Al; 0.05 mAs each film

Table 4. Reference summary

| Author | Organs/Site | Dose | Film | kV | mm Al | mAs | Techniques Used: Favorable | Comments: Unfavorable |
|---|---|---|---|---|---|---|---|---|
| Blackman (10) | Free air (SSD-5 cm) | 33 mR | screen (fast) | 60 | 2.5 | 0.5<br>0.1 | | |
| | Mucosa (SSD-2 cm) | 240 mR | | | | | | |
| | (SSD-3 cm) | 110 mR | | | | | | |
| | Skin (SSD-5 cm) | 8 mR<br>23 mR | | | | | | |
| Gershon-Cohen et al (12) | Oral tissues | 1-1.4 rad. | | 70 | 2.1<br>2.5 (HVL) | 0.47<br>0.1 | | |
| Guzman (5) | Palate (SSD-1.2 cm) | 530 mR | non-screen | 52.5 | | 0.3 | 1. Geometric blur 1/3 of conventional techniques.<br>2. Superior visualization<br>3. High quality and definition.<br>4. Interpretations more decisive and accurate.<br>5. Magnification factor desirable.<br>6. Radiation dosage lower than conventional techniques. | 1. Varying degrees of distortion.<br>2. Overlapping<br>3. Magnification factor a disadvantage for endodontia, space analysis.<br>4. Minor deviation in positioning of tube stem produces marked asymmetry of radiograph. |
| | Tongue (SSD-2.5 cm) | 380 mR | | | | | | |
| | cheek, mucosa (SSD-3.0 cm) | 260 mR | | | | | | |
| | Incisors Ling., max. (SSD-4.0 cm) | 130 mR | | | | | | |
| | Skin exit | | | | | | | |
| | Molar | 8 mR | | | | | | |
| | Premolar | 14 mR | | | | | | |
| | Incisor | 18.5 mR | | | | | | |
| | Free air | 1.5 R/ sec. | | 52.5 | | 1 | | |
| | (SSD-1.0 cm) | 1.18 R/ sec. | | 60 | | 0.5 | | |

Table 4. Reference summary (continued)

| Author | Organs/Site | Dose | Film | kV | mm Al | mAs | Techniques Used / Comments: Favorable | Unfavorable |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | **Intraoral** | |
| Isard et al (6)[1] | 1.3 cm fma. tube | 14.0 R | | 70 | 2.1 2.5 (HVL) | 1.0 | 1. Unusually advantageous exposures of facial, neck structures.<br>2. Practures better visualized.<br>3. Avoid body section films.<br>4. Limited radiation exposure.<br>5. Better sialography and hyoid bone. | |
| | 2.2 cm fma. tube | 8.0 R | | | | | | |
| | 5.5 cm fma. tube | 1.1 R | | | | | | |
| | | | | | | | **Extraoral** | |
| | | | | | | | 1. Useful for knee, shoulder and elbows - joints in painful conditions.<br>2. Possible value in mammography, intracavitary applications. | |
| Jung (11) | Oral tissues | 500 mR | no screens Two exposures | | 3.5 | | 1. Dose smaller than conventional techniques | |
| | Gonadal[2] | 254 mR<br>50 mR[3] | | | | | | |

[1]Measurements from Suntha and Galkin, Radiation Safety Report
[2]Lap doses; therefore, actually 1/10 less than measurements
[3]Using lead shield

Table 4. Reference summary (continued)

| | | | Techniques Used | | | | Comments | |
|---|---|---|---|---|---|---|---|---|
| Author | Organs/Site | Dose | Film | kV | mm Al | mAs | Favorable | Unfavorable |
| Morani et al (7) | Average exp. dose | 1.4 rads | Single non-screen | | | 0.1 | 1. Striking clarity.<br>2. Free of superimposed shadows.<br>3. Exceptional detail.<br>4. No image blurring.<br>5. Image magnified 2-3 X.<br>6. No penumbra. | |
| Morch et al (15) | Thyroid | 26 mR[1]<br>45 mR[2] | | 50 | ? | ? | | |
| | Eye (lateral) | | | | | | | |
| | Orbital Wall | 23 mR<br>265 mR | | | | | | |
| | Mandible (angle) | 171 mR<br>350 mR | | | | | | |
| Van Aken (19) | Complete mouth | 19 gm-rads[3] | Screen low speed two exposures | | | | 1. Dose smaller than conventional technique.<br>2. Relatively good detail. | 1. Poor projection of upper molar area.<br>2. Often overlapping of teeth. |

[1]Panoramix
[2]Conventional Techniques (periapical)
[3]Integral absorbed dose

The values read from the dosimeter situated beneath the ventral surface of the tongue, and resting on the mucosa of the mylohyoid muscle (floor of the mouth) at the lingual frenum, represents a good example of the attenuation provided by the muscular structure of the tongue. During the mandibular projection, with the tube inclined 20° inferiorly the mid-dorsum of the tongue was exposed similarly to the palatal tissues during the opposite projection since the tube is touching the tongue. Therefore, references to the palatal exposures may be synonomous with the exposures of the dorsum of the tongue in roentgens.

Most of the authors in table 4 have reported values at sites monitored about the mouth of clinical subjects during Panoramix roentgenography. Despite differences of film type, kV and/or mAs, Guzman (5), Blackman (10), and Jung (11) report dose values which are essentially in agreement with one another. Our evidence appears to corroborate their data also. Morani (7) and Gershon-Cohen (12) show nearly identical values in terms of rads. Woodcock and Properzio (4) apparently agree with Isard (6) concerning ranges of tube output.

Conventional complete mouth examinations gave various skin exposures for techniques corresponding to ours. Richards (13) reported 6.5 R and Bjarngard (14) reported 7-50 rads, each using a slow speed film. Our results are near the lower end of this range after adjusting for film speed differences.

## 5.3 Critical Organs

The radiosensitive organs of concern closest to the tube are the lens of the eye and the thyroid. Exposures in the phantom were 20 and 5 mR per examination, respectively.

As shown by figure 10, a 2 to 1 ratio was noted when comparing infraorbital exposure levels between phantom and human subjects. In the phantom, the lens measurements were similar to the infraorbital readings. By analogy therefore, the human lens received less than 40 mR, and occasionally 10 mR per examination.

The internal and external thyroid recordings in the phantom are almost the same. There was also good agreement at these respective "skin" sites between the phantom and humans. Therefore, by analogy, the thyroid tissue exposures in patients, averaged 5 mR for either examination.

Only Jung (11) and Morch (15) measured doses specifically for the critical organs. Jung reports a gonadal dose of roughly 25 mR, or about 5 mR with a lead apron. Morch compares Panoramix and conventional doses to the eyes and thyroid, with the former technique resulting in one-half to one-tenth less exposure than the latter. Our in vivo/ in vitro measurements relative to panography were in close agreement.

Conventional complete mouth examinations gave various critical organ exposures for techniques corresponding to ours. Richards and Webber (16) reported 2.1 R to the eye and 1.3 R to the thyroid with fast film, whereas Bjarngard (14) reported 11,000 mrads and 900 mrads respectively with slow film. Our results were less by a factor of 50 for the eye and 260-30 for the thyroid, respectively, after film speed adjustments.

## 5.4 Phantom Equivalence to Humans

Although equivalence of any phantom to a human is not absolute, sufficient evidence was presented to demonstrate a reasonably good similarity between them as anticipated, both dosimetrically and radiographically (17, 18). The measurements for the corresponding external sites of the phantom and patients were shown to agree considering anatomical variations. Therefore, we may assume from the relationship of the internal and external phantom data that the calculated human internal exposures are also valid. Radiographs of the phantom were lifelike enough to a panel of clinicians so that the diagnostic film study provided a valuable means of determining acceptable technique factors.

## 5.5 Additional Filtration

The use of the filtration sleeve appeared to make little difference in the exposure of critical organs (fig. 10). The radiation at the face was about the same for best film quality regardless of initial spectral quality because of tissue absorption of the softer rays. At the human infraorbital sites, figure 10 illustrates a maximum ratio of 3.5:1 between the softest and hardest x-ray techniques. Elsewhere in the graph few differences were noted.

However, since added filtration did cause a significant exposure reduction near the tube, one should consider the potential merits of more filtration.

Perhaps the aluminum filter could be tapered, allowing greater film density in the posterior regions, thereby more closely matching the density of the anterior portion of the films. In conventional techniques, dentists are accustomed to controlling film densities between regions of both jaws, by varying either kV and/or mAs.

## 5.6 Projections

The cranio-facial structures can be displayed as an excellent panoramic image by one of the following two examinations, using the Panoramix (5,7,15,19).

5.6.1 A single 8-inch x 10-inch x-ray film incorporates both dental arches, both jaws, including the ascending rami of the mandible, and at times, the temporamandibular articulations, the para nasal sinuses, and the facial skeleton (fig. 13).

5.6.2 Two 4-inch x 10-inch films taken above and below the occlusal plane, are also suitable techniques (fig. 14). The latter pair provides films of the above structures with no shadows superimposed, excellent clarity, and little distortion.

## 5.7 Film

Nonscreen films offer exceptionally fine detail and striking clarity in those situations for which these qualities are neccessary. Most of the film used in conventional dental radiology is of this type. Nevertheless, many routine survey examinations are performed using screen film, as demonstrated by the Panorex and Orthopantomograph, which are laminographic, panographic devices.

The Panoramix is also a panographic method of radiology, minus certain of the disadvantages of laminography inherent with the movement of patient, tube, and film. The proper combination of screens and films, as described by Blackman (10), would be quite useful, if available in the USA also. Moreover, the option of selecting a system which also has the added benefit of reducing doses by a factor of 10 or more, should be available. Such a reduction may be accomplished by a combination of one or more of the following:

1. Machine alteration
2. Proper tube accessory
3. Screen selection
4. Film selection

Figure 13. Photo of 8-inch by 10-inch radiograph of phantom

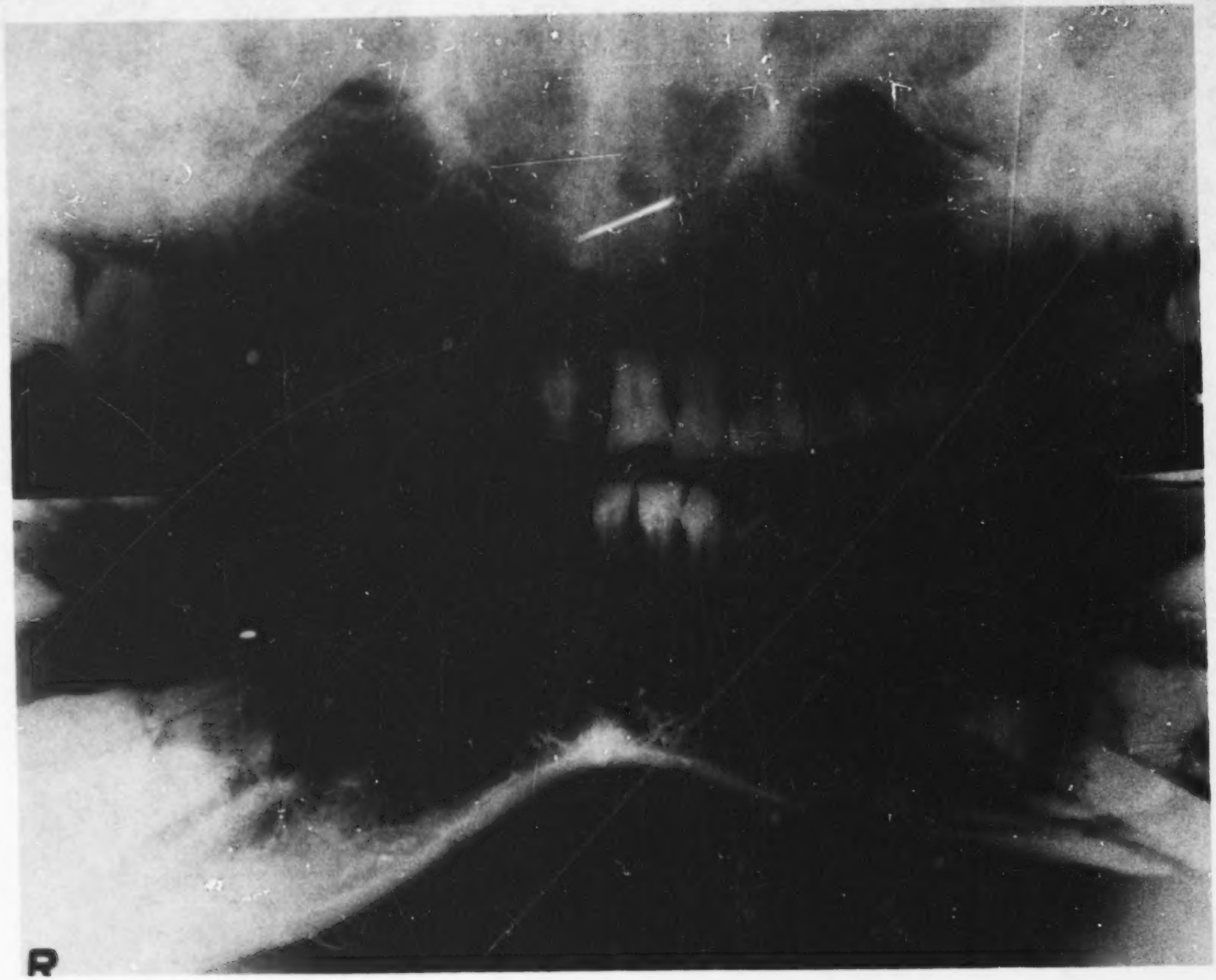


Figure 14. Photo of two 4-inch by 10-inch radiographs of maxillary and mandibular projections of the phantom

## 5.8 Scatter

Measurements of scatter radiation from this method of panography range from one hundredths to one thousandths of the amounts encountered from any single periapical or bitewing dental radiograph, as reported by Rolofson et al (20). It appears, therefore, that exposures from scatter radiation, using the Panoramix, would not exceed scatter exposures encountered from any conventional complete mouth roentgenography.

## 6. CONCLUSIONS

The radiation exposures to the critical organs of the patient were much less than reported exposure levels for conventional, intra-oral, complete-mouth radiography.

Radiation exposure levels to the tongue and palatal areas were found to be similar to reported skin exposures of the face from conventional complete mouth procedures. The mucosa and the skin are each of ectodermal origin, a relatively nonradiosensitive structure, and more radioresistant than the tissues of critical organs.

There appears to be good correlation, radiographically and dosimetrically, between the Rando phantom and the human subjects. Measurements impossible to assess with human subjects can be extrapolated from the phantom data.

Scatter radiation levels per examination are less than 0.25 mR at the operator site, and apparently less than those from a conventional complete mouth examination. Therefore, the usual shielding requirements appear adequate.

The anode tube collimating shield and filtration sleeve are each effective in their respective roles. However, they cannot be used together if so desired.

Based on the foregoing, the recommendations of NBS Handbook No. 76 (1), of NCRP Report #33 (2), relative to the minimum source-skin distance and of ICRP Report #3 (3), regarding body contact for dental X-ray units, should not be applicable to the Panoramix. Such special purpose machines must be evaluated in terms of the radiation exposures associated with the type of operation necessary to realize the maximum benefit from their use.

The scientific literature indicates that the Panoramix is an adjunct to conventional dental roentgenography and, in fact, offers distinct advantages in visualizing the maxillo-facial structures of the head. This subjective impression was apparent within this study too. The use of x-rays herein appears both judicious and effective.

## 7. RECOMMENDATIONS

Consideration should be given to:

(1) Reducing the tube milliamperage or exposure timer settings to permit the use of medical x-ray screen films with screen cassettes already available.

(2) Constructing a tube filtration sleeve, one side of which would be tapered aluminum, thicker over the anode, in order to produce films with more uniform overall density.

(3) Constructing a tube collimating shield capable of slipping over the aluminum filtration sleeve.

(4) Producing and evaluating radiographs from each of the foregoing changes to determine the diagnostic acceptability of such films.

(5) Designing and producing a collimator to permit new extraoral examination techniques to be developed; i.e., using screened occlusal type film cassettes, extraoral periapical size films, etc.

(6) Developing separate radiation protection recommendations for intracavitary machine for diagnostic purposes.

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A STUDY OF HEAD AND NECK EXPOSURES FROM PANORAMIX (R) ROENTGENOGRAPHY - James J. McMahon, D.D.S.; February 1970; DEP 70-5; DEP, BRH, EHS, PHS, DHEW.

Accession No.

A study was made of body organ exposures resulting from maxillo-facial panographic procedures using the Panoramix an intracavitary radiographic machine. Diagnostic examinations were simulated on a phantom and performed on several patients under laboratory conditions.

Thermoluminescent dosimeters were placed at selected internal and external sites of a phantom human bust and at corresponding sites on several dental patients. Various operating parameters and techniques were used and the radiation at various locations was measured. The laboratory and clinical experiments were closely coordinated in order to compare data.

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KEY WORDS:
Dental, Diagnostic, Dose, Dosimetry, Exposure, Intraoral, Measurements, Panoramic, Patient, Phantom, Radiographic procedures, Radiography, Roentgenology, Thermoluminescent dosimetry, Panoramix, Critical organs.

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